Instituto Politécnico de Tomar

Escola Superior de Tecnologia de Tomar

Engenharia Informática

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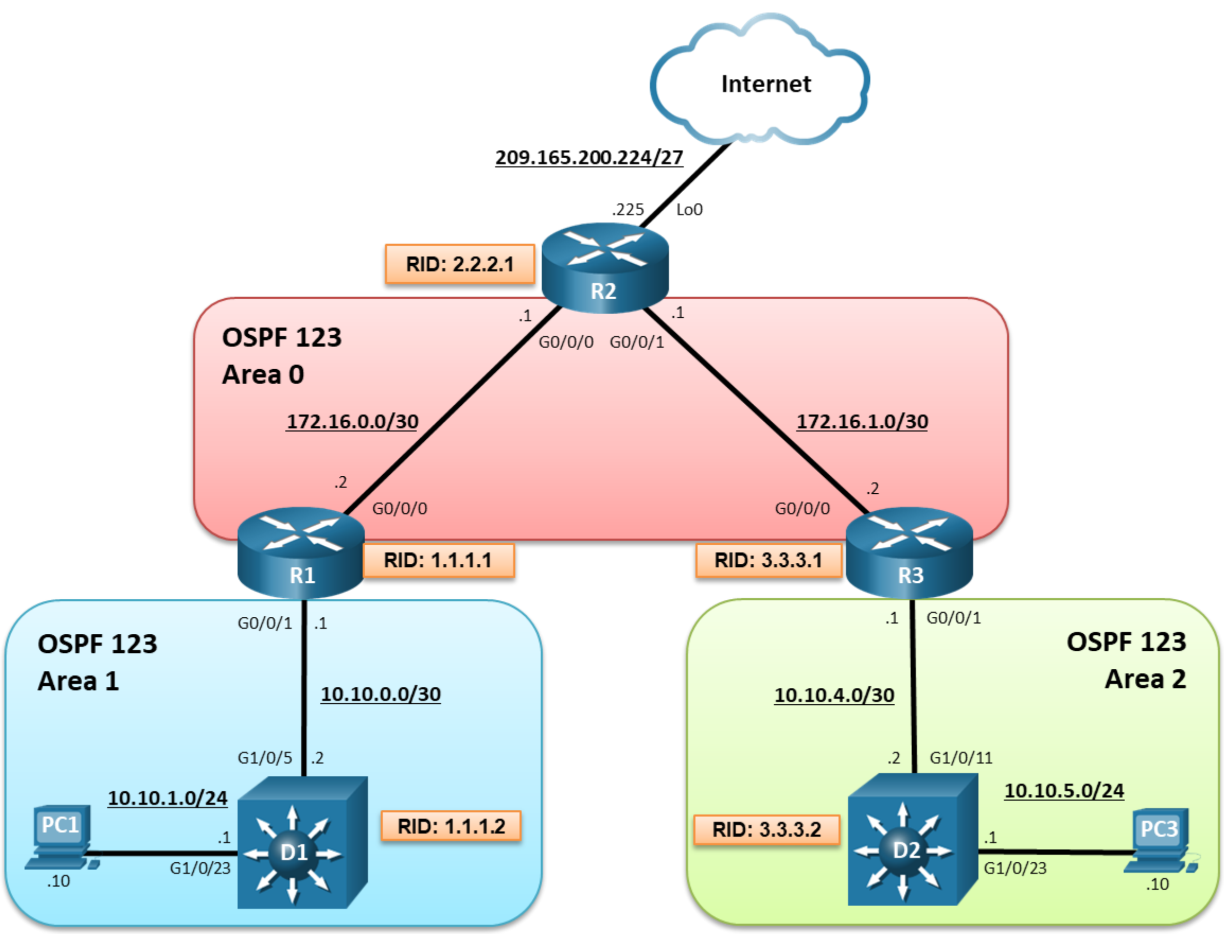
Trabalho Laboratorial 3: Implement Multi-area OSPFv2 Topology
Based on Cisco CCNA lab guide.

Topology



Addressing Table

Device	Interface	IPv4 Address
R1	G0/0/0	172.16.0.2/30
	G0/0/1	10.10.0.1/30
R2	Lo0	209.165.200.225/27
	G0/0/0	172.16.0.1/30
	G0/0/1	172.16.1.1/30
R3	G0/0/0	172.16.1.2/30
	G0/0/1	10.10.4.1/30
D1	G1/0/11	10.10.0.2/30
	G1/0/23	10.10.1.1/24
D2	G1/0/11	10.10.4.2/30
	G1/0/23	10.10.5.1/24
PC1	NIC	10.10.1.10/24
PC2	NIC	10.10.5.10/24

Objectives

Part 1: Build the Network and Configure Basic Device Settings and Interface Addressing

Part 2: Configure and Verify Multiarea OSPF for IPv4 on R1, D1, and D2

Part 3: Exploring Link State Announcements

Background / Scenario

To make OSPF more efficient and scalable, OSPF supports hierarchical routing using the areas. An OSPF area is a group of routers that share the same link-state information in their link-state databases (LSDBs). When a large OSPF area is divided into smaller areas, it is called multiarea OSPF. Multi-area OSPF is useful in larger network deployments to reduce processing and memory overhead.

In this lab you will configure multiarea OSPF version 2 for IPv4. This lab was specifically designed to use three routers and two Layer 3 switches.

Note: This lab is an exercise in developing, deploying, and verifying how multiarea OSPF operates and does not reflect networking best practices.

Instructions

Part 1: Build the Network and Configure Basic Device Settings and Interface Addressing

In Part 1, you will set up the network topology and configure basic settings and interface addressing on the routers and Layer 3 switches.

Step 1: Cable the network as shown in the topology.

Attach the devices as shown in the topology diagram, and cable as necessary.

Step 2: Configure basic settings.

a. Disable DNS lookup.

b. Configure device names as shown in the topology.

c. Configure password encryption.

d. Assign **class** as the privileged EXEC password.

e. Assign **cisco** as the console and vty passwords.

f. Configure a MOTD banner to warn users that unauthorized access is prohibited.

g. Configure **logging synchronous** for the console line.

h. Configure the IP addresses listed in the Addressing Table for all interfaces.

i. Configure a description for each interface with an IP address.

j. Configure the clock rate, if applicable, to the DCE serial interface.

k. Copy the running-configuration to the startup-configuration.

l. Save the running configuration to startup-config.

m. Verify the interface status using the **show ip interface brief** command.

n. Verify direct connectivity between all five devices. R1 is shown as an example.

```
R1# ping 10.10.0.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.0.2, timeout is 2 seconds:
..!!!
Success rate is 60 percent (3/5), round-trip min/avg/max = 2/2/2 ms
```

Note: All five devices should be able to reach the other directly connected networks. Troubleshoot if necessary.

Part 2: Configure Multiarea OSPFv2

In this part, you will implement multiarea OSPF. Multiarea OSPF defines a two-layer area hierarchy using a backbone area interconnecting regular areas. This is useful in larger network deployments to reduce processing and memory overhead.

In this topology, OSPF has the following three areas defined:

- **Area 0** – The backbone area. All regular areas should connect to the backbone area.
- **Area 1** and **Area 2** – Regular OSPF areas that connect to the backbone area.

The routers and switches in the topology are used in the following roles:

- **Internal routers** - R2 is an internal router in Area 0, D1 is internal in Area 1, and D2 is internal in Area 2.
- **Backbone routers** - R1, R2, and R3 are backbone routers as they all have interfaces in Area 0.
- **Area Border routers (ABRs)** – R1 and R3 are ABRs because they connect regular areas (i.e., Area 1 and Area 2) to the backbone Area 0.
- **Autonomous System Boundary router (ASBR)** – R2 is an ASBR because it connects to another non-OSPF network.

Step 1: Configure OSPF on all routers and L3 switches.

a. Configure OSPF on all routing devices according to the network diagram. Changing the reference bandwidth to a higher value allows for a differentiation of cost between higher-speed interfaces.

```
D1(config)# router ospf 123
D1(config-router)# router-id 1.1.1.2
D1(config-router)# auto-cost reference-bandwidth 1000
% OSPF: Reference bandwidth is changed.
        Please ensure reference bandwidth is consistent across all routers.
D1(config-router)# network 10.10.0.0 0.0.0.3 area 1
D1(config-router)# end
```

b. Verify the OSPF configuration on all routing devices using the **show ip protocols** command.

```
D1# show ip protocols
…
Routing Protocol is "ospf 123"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 1.1.1.2
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.10.0.0 0.0.0.3 area 1
    10.10.1.0 0.0.0.255 area 1
  Routing Information Sources:
    Gateway         Distance      Last Update
  Distance: (default is 110)
```

The output confirms the router ID, and the number of areas, and the networks advertised. Notice there are no Routing Information Sources because there are no OSPF neighbors.

c. Verify the OSPF interfaces using the **show ip ospf interface brief** command on each routing device.

```
D1# show ip ospf interface brief
Interface    PID   Area            IP Address/Mask    Cost  State Nbrs F/C
Gi1/0/23     123   1               10.10.1.1/24       10    DR    0/0
Gi1/0/11     123   1               10.10.0.2/30       10    DR    0/0
```

The output confirms that both G1/0/11 and G1/0/23 interfaces were correctly assigned to Area 1.

d. Verify which OSPF neighbors R1 has established an adjacency with using the **show ip ospf neighbor** command.

```
R1# show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
1.1.1.2           1   FULL/DR         00:00:31    10.10.0.2       GigabitEthernet0/0/1
```

The output confirms that R1 has one neighbor (i.e., 1.1.1.2 = D1), they have a full adjacency established, the IP address of D1 is 10.10.0.2, and R1 can reach D1 using its G0/0/1 interface.

e. Use the **show ip ospf neighbor detail** command to get additional information about neighbor adjacencies.

```
R1# show ip ospf neighbor detail
 Neighbor 1.1.1.2, interface address 10.10.0.2, interface-id 38
```

```
In the area 1 via interface GigabitEthernet0/0/1
Neighbor priority is 1, State is FULL, 6 state changes
DR is 10.10.0.2 BDR is 10.10.0.1
Options is 0x12 in Hello (E-bit, L-bit)
Options is 0x52 in DBD (E-bit, L-bit, O-bit)
LLS Options is 0x1 (LR)
Dead timer due in 00:00:34
Neighbor is up for 00:19:09
Index 1/1/1, retransmission queue length 0, number of retransmission 0
First 0x0(0)/0x0(0)/0x0(0) Next 0x0(0)/0x0(0)/0x0(0)
Last retransmission scan length is 0, maximum is 0
Last retransmission scan time is 0 msec, maximum is 0 msec
```

As shown, the output confirms various information about the OSPF neighbor including DR and BDR status.

f. Verify the OSPF routes in the routing table using the **show ip route ospf** command.

g. Get detailed information on how R1 learned about the OSPF entry using the **show ip route ospf 10.10.1.0** command.

Step 2: Verify end-to-end connectivity.

The multiarea OSPF network is now completely configured. We now need to verify the operation of OSPF.

a. From PC1, verify end-to-end connectivity by pinging PC3

b. Verify the route taken by doing a traceroute to PC3 from PC1.

Part 3: Explore Link State Announcements

In this part, you will verify that the network has converged and explore how link-state advertisements (LSAs) are used as the building blocks for the OSPF link-state database (LSDB).

OSPF routers create LSAs for every directly connected OSPF-enabled interface. It then sends those LSAs to OSPF peers to form adjacencies. Individually, LSAs are database records providing specific OSPF network details. Combined, they describe the entire topology of an OSPF area.

OSPF routers uses six LSA types for IPv4 routing:

- **Type 1, router LSA** – All OSPF-enabled routers create and send type 1 LSAs. The LSAs are immediately propagated within the area. An ABR does not forward the LSA outside the area.
- **Type 2, network LSA** - Only a DR generates and advertises a type 2 LSA. The type 2 network LSA lists each of the attached routers that make up the transit network, including the DR itself, and the subnet mask that is used on the link. The DR floods the LSA to all OSPF routers (i.e., 224.0.0.5) on the multiaccess network. The content of the displayed type 2 LSA describes the network segment listing the DR address, the attached routers, and the used subnet mask. This information is used by each router participating in OSPF to build the exact picture of the described multiaccess segment, which cannot be fully described with just type 1 LSAs.
- **Type 3, summary LSA** - ABRs do not forward type 1 or type 2 LSAs into other areas. ABRs flood type 3 LSAs to propagate network information to other areas. Type 3 summary LSAs describe networks that are in an area to the rest of the areas in the OSPF autonomous system.
- **Type 4, ASBR summary LSA** – When there is an ASBR in the OSPF domain, it advertises itself using a special type 1 LSA. When an ABR receives this type 1 LSA, it builds a type 4 LSA to advertise the existence of the ASBR and floods it to other areas. Subsequent ABRs regenerate a type 4 LSA and flood it into their areas.

- **Type 5, AS external LSA** – ASBRs generate a type 5 external LSAs to advertise external OSPF routes to the OSPF domain. Type 5 LSAs are originated by the ASBR and are flooded to the entire autonomous system.
- **Type 7, NSSA external LSA** – This is a special LSA generated by a not-so-stubby (NSSA) ASBR to advertise external OSPF networks to an OSPF domain. The ABR converts the type 7 LSA to a type 5 LSA and propagates it to other areas. An NSSA network is a special-case area type used to reduce the amount of flooding, the LSDB size, and the routing table size in routers within the area.

Note: Other LSAs also exist but are out of scope of this lab.

The focus of this section will be on LSA types 1, 2, and 3 which are used to identify intra-area and interarea routes.

Step 1: Verify OSPF and Exploring LSAs on D1.

D1 is an internal router and generates type 1 LSAs. It is also the DR on the link connecting to R1 and therefore generates type 2 LSAs.

a. D1 learned about these networks from LSAs. A router maintains a LSDB for each area it has interfaces in. Because D1 is an internal OSPF router, it will only have entries for Area 1. To display the contents of the LSDB of D1, use the **show ip ospf database** command.

```
D1# show ip ospf database

              OSPF Router with ID (1.1.1.2) (Process ID 123)

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         1806        0x80000005 0x00DC15 1
1.1.1.2         1.1.1.2         167         0x80000005 0x001AA6 2

                Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.10.0.2       1.1.1.2         167         0x80000003 0x00B462

                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.10.4.0       1.1.1.1         1806        0x80000002 0x00A86E
10.10.5.0       1.1.1.1         1807        0x80000002 0x0014F4
172.16.0.0      1.1.1.1         1807        0x80000002 0x00DBA1
172.16.1.0      1.1.1.1         1807        0x80000002 0x00DAA0

                Summary ASB Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
2.2.2.1         1.1.1.1         1807        0x80000002 0x00131C

                Type-5 AS External Link States

Link ID         ADV Router      Age         Seq#       Checksum Tag
```

```
0.0.0.0         2.2.2.1         1939        0x80000002 0x009F90 123
```

Notice how the command output is divided into the following five sections:

- **Router Link States** – These are the type 1 LSAs received by D1 and they identify the routers (i.e., 1.1.1.1 = R1, 1.1.1.2 = D1) in Area 1 that sent them, and the number of links that the routers have in the area. Therefore, R1 only has one interface in Area 1 and D1 has 2 interfaces in Area 1.
- **Net Link States** – These are the type 2 LSAs generated by the DR. In our example, the DR is 1.1.1.2 (i.e., D1) on the link 10.10.0.2.
- **Summary Net Link States –** These are the type 3 LSAs describing remote networks (i.e., our O IA networks or interarea routes) and the router that advertised them to D1.
- **Summary ASB Link States –** This is a type 4 LSA sent by the ABR (i.e., 1.1.1.1 = R1) advertising that there is an ASBR in the network (i.e., 2.2.2.1).
- **Type-5 AS External Link States** – This is a type 5 LSA advertising a default route (i.e., 0.0.0.0) and the router that is advertising it (i.e., 2.2.2.1).

b. Additional information about the Router Link States type 1 LSA can be gathered using the **show ip ospf database router** command.

```
D1# show ip ospf database router

            OSPF Router with ID (1.1.1.2) (Process ID 123)

                Router Link States (Area 1)

  Routing Bit Set on this LSA in topology Base with MTID 0
  LS age: 843
  Options: (No TOS-capability, DC)
  LS Type: Router Links
  Link State ID: 1.1.1.1
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000007
  Checksum: 0xD817
  Length: 36
  Area Border Router
  Number of Links: 1

    Link connected to: a Transit Network
     (Link ID) Designated Router address: 10.10.0.2
     (Link Data) Router Interface address: 10.10.0.1
      Number of TOS metrics: 0
       TOS 0 Metrics: 1


 LS age: 1196
  Options: (No TOS-capability, DC)
  LS Type: Router Links
  Link State ID: 1.1.1.2
  Advertising Router: 1.1.1.2
  LS Seq Number: 80000006
  Checksum: 0x18A7
```

```
    Length: 48
    Number of Links: 2

  Link connected to: a Transit Network
       (Link ID) Designated Router address: 10.10.0.2
       (Link Data) Router Interface address: 10.10.0.2
        Number of MTID metrics: 0
         TOS 0 Metrics: 1

      Link connected to: a Stub Network
       (Link ID) Network/subnet number: 10.10.1.0
       (Link Data) Network Mask: 255.255.255.0
        Number of MTID metrics: 0
         TOS 0 Metrics: 10
```

The output provides more information about the type 1 LSAs. The first router link (i.e., type 1) LSA is from R1 (i.e., 1.1.1.1). It is an ABR with only 1 link in Area 1 which is the transit network connecting to D1. The second router link portion identifies the transit network connecting to R1 and the stub network of D1 (i.e., 10.10.1.0/24).

An OSPF link can be connected to a stub, to another router (point-to-point), or to a transit network. The transit network usually describes an Ethernet segment which can include two or more routers. If the link is connected to a transit network, the LSA also includes the IP address of the DR.

c. To learn more about type 2 network LSAs, use **show ip ospf database network** command.

```
D1# show ip ospf database network

            OSPF Router with ID (1.1.1.2) (Process ID 123)

                Net Link States (Area 1)

  LS age: 845
  Options: (No TOS-capability, DC)
  LS Type: Network Links
  Link State ID: 10.10.0.2 (address of Designated Router)
  Advertising Router: 1.1.1.2
  LS Seq Number: 80000005
  Checksum: 0xB064
  Length: 32
  Network Mask: /30
        Attached Router: 1.1.1.2
        Attached Router: 1.1.1.1
```

The content of the type 2 LSA describes the network segment listing the DR address, the attached routers, and subnet mask using CIDR notation. This information is used by each router in the area to build the exact picture of the described multiaccess segment, which cannot be fully described with just type 1 LSAs.

d. To learn more about type 3 summary LSAs, use **show ip ospf database summary** command.

```
D1# show ip ospf database summary
```

```
            OSPF Router with ID (1.1.1.2) (Process ID 123)

                Summary Net Link States (Area 1)

  LS age: 987
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.10.4.0 (summary Network Number)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000005
  Checksum: 0xA271
  Length: 28
  Network Mask: /30
        MTID: 0         Metric: 3

  LS age: 987
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 10.10.5.0 (summary Network Number)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000005
  Checksum: 0xEF7
  Length: 28
  Network Mask: /24
        MTID: 0         Metric: 13

  LS age: 988
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 172.16.0.0 (summary Network Number)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000005
  Checksum: 0xD5A4
  Length: 28
  Network Mask: /30
        MTID: 0         Metric: 1

  LS age: 989
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(Network)
  Link State ID: 172.16.1.0 (summary Network Number)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000005
  Checksum: 0xD4A3
  Length: 28
  Network Mask: /30
        MTID: 0         Metric: 2
```

The output lists four type 3 LSAs. The LSAs identify the interarea networks, which ABR advertised, and the network mask using CIDR notation.

e. To learn more about type 4 summary LSAs, use **show ip ospf database asbr-summary** command.

```
D1# show ip ospf database asbr-summary

            OSPF Router with ID (1.1.1.2) (Process ID 123)

                Summary ASB Link States (Area 1)

  LS age: 591
  Options: (No TOS-capability, DC, Upward)
  LS Type: Summary Links(AS Boundary Router)
  Link State ID: 2.2.2.1 (AS Boundary Router address)
  Advertising Router: 1.1.1.1
  LS Seq Number: 80000006
  Checksum: 0xB20
  Length: 28
  Network Mask: /0
        MTID: 0         Metric: 1
```

The output lists one type 4 LSA advertised by R1 identifying 2.2.2.1 as an ASBR.

f. Finally, to learn more about type 5 AS external link LSAs, use **show ip ospf database external** command.

```
D1# show ip ospf database external

            OSPF Router with ID (1.1.1.2) (Process ID 123)

                Type-5 AS External Link States

  LS age: 1024
  Options: (No TOS-capability, DC, Upward)
  LS Type: AS External Link
  Link State ID: 0.0.0.0 (External Network Number )
  Advertising Router: 2.2.2.1
  LS Seq Number: 80000006
  Checksum: 0x9794
  Length: 36
  Network Mask: /0
        Metric Type: 2 (Larger than any link state path)
        TOS: 0
        Metric: 1
        Forward Address: 0.0.0.0
        External Route Tag: 123
```

The output lists one type 5 LSA identifying that 0.0.0.0/0 is available from 2.2.2.1 (i.e., R2).

Step 2: Verify OSPF and exploring LSAs on an ABR R1.

R1 is an ABR and therefore its link state database is different when compared with D1, use the following commands to establish the differences:

- **show ip ospf database router**
- **show ip ospf database network**

- **show ip ospf database summary**
- **show ip ospf database asbr-summary**
- **show ip ospf database external**

Step 3: Verify OSPF and exploring LSAs on the ASBR R2.

Explain the output of the following commands

- **show ip ospf database router**
- **show ip ospf database network**
- **show ip ospf database summary**
- **show ip ospf database asbr-summary**
- **show ip ospf database external**

Part 5: Link State Database optimizations

Step 1: Configure Area 1 as a stub area.

Step 2: Verify the link state database differences on R1 and D1.

Step 3: Configure Area 2 as a totally stub area.

Step 4: Verify the link state database differences on R3 and D2.